EUR 4597 e

COMMISSION OF THE EUROPEAN COMMUNITIES

THE EFFECT OF VARIOUS IMPURITIES ON THE ELECTRICAL CONDUCTIVITY OF ORGANIC COOLANT LIQUIDS

by

D. VAN VELZEN, H. LANGENKAMP and G. SERRINI

1971

Joint Nuclear Research Centre
Ispra Establishment - Italy

Chemistry Department
Organic Chemistry
and
Analytical and Inorganic Chemistry

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Printed by Guyot, s.a., Brussels
Luxembourg, January 1971

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It appears that it is not possible to use the electrical conductivity as a measure of the total chlorine content, since insufficiently dissociated compounds do not influence the electrical conductivity. Most probably, this type of compounds is neither very active as a fouling promotor.

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ABSTRACT

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It appears that it is not possible to use the electrical conductivity as a measure of the total chlorine content, since insufficiently dissociated compounds do not influence the electrical conductivity. Most probably, this type of compounds is neither very active as a fouling promotor.

As a general conclusion it is stated that continuous recording of the electrical conductivity in high purity organic coolants is an utmost useful operation, since any increase of the conductivity is caused by an increase of the impurity content.

KEYWORDS

IMPURITIES
ELECTRIC CONDUCTIVITY
ORGANIC COOLANT
COOLANT LOOPS
ESSOR
MEASUREMENT
CHLORINE
FOULING
RESIDUES
ADSORPTION
QUARTZ
WOOL

CONTENTS

1. INTRODUCTION *)

Electrical conductivity of organic coolants is dependent on a large number of factors. In the first place it considerably changes with temperature and secondly it is influenced by a variety of impurities and their concentration.

One of these impurities is chlorine, which is known to be amongst the most hazardous contaminants in organic coolants for nuclear applications: Its promotes the corrosion of metal parts of the circuit, including pressure tubes [1], enhances the deposit formation on hot surfaces (fouling) [2] and plays and important part in the hydrogen weight gain of zirconium alloys [3].

For these reasons it is necessary to restrict the chlorine concentration of organic coolants to 0.1 - 0.2 ppm.

Concentrations of this order of magnitude can be analytically determined by activation analysis or by chemical means, but these methods require special sampling and are rather tedious.

A simple, continuous recording device would be very suitable. Continuous measurement of the electric conductivity has been proposed for this purpose.

During operation of the U-3 and X-2 loops at Chalk River and in the WR-1 reactor at Whiteshell the Canadians used the electrical conductivity as one of the main yardsticks for the purity of the coolant [4,5].

The success of these measurements has given rise to the proposal of a similar device for coolant control in the Essor reactor. Preliminary static measurements have been carried out at the Physical Chemistry Service of the CCR Euratom [6], followed by design and development of a suitable, continuously recording apparatus with an appropriate conductivity meter [7].

This device has been inserted into a bye-pass of the Technology loop and been in operation during three weeks, at a temperature of approximately 380°C. The coolant was OM-2 Progil.

In the Technology loop the possibilities of experimentation with the conductivity cell are very restricted, because the quantity of impurities in the coolant should always be kept at the absolute minimum. Consequently, the effect of various chlorinated compounds, temperature etc ... could not be established.

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*) Manuscript received on 28 October 1970

For this reason additional experimental work has been carried out in a small loop belonging to the Organic Chemistry Section.

The present report is dedicated to these investigations.

2. EQUIPMENT AND OPERATION

The experimental work has been carried out in a small loop, consisting essentially of a 30 liters storage vessel coupled to a centrifugal pump and appropriate piping.

A sketch of the apparatus is given in Fig. 1.

The pump has been manufactured by the firm Salmson (France), its maximum capacity is 6 $m^3.h^{-1}$.

Flow control is performed by means of a motorised three-way valve, controlling the main and bye-pass flow rate. An inductance flow meter (manufacture: Rochar, France) is recording the flow rate through the test section, which is generally about 1000 $l.h^{-1}$. The installation can be heated by resistance wire to approximately 400°C and the maximum admissible pressure is 6.5 atm.

The experiments were for the greater part carried out with Progil OMD. In this case, the maximum temperature and pressure are much lower, due to the relatively high vapour pressure and possible losses of biphenyl due to evaporation and sublimation. For this reason the majority of the experiments were performed at 150-200°C and at atmospheric pressure. Operation at atmospheric pressure allowed the maintenance of a low water content. Excess of water caused by the addition of various test compounds readily evaporated.

The conductivity cell consists essentially of two stainless steel electrodes in an annular arrangement, suitably spaced and insulated by alumina spacing rings. It has been designed for operating at temperatures around 400°C and pressures of approximately 20 atm. A detailed design of the cell is given in Fig. 2.

The cell constant has been determined by the Physical Chemistry Service by means of capacity measurements with known dielectrics [8,9]. Its value is 0.88×10^{-3} cm^{-1}. The product of the conductance (mho) and the cell constant yields the electrical conductivity ($mho.cm^{-1}$).

Conductance measurements are performed with the aid of the conductance meter MAC-1, developed by the Engineering Department [7]. The principle is that a square wave with a frequency of 10 Hz is generated, which causes a weak alternative current to pass through the fluid.

A known resistance placed in series with the generator and the cell enables the measurement of a tension which is proportional to the current.

Under these conditions no polarisation of the fluid will occur. The meter is able to measure conductances in the range from 10^{-5} to 10^{-10} mho.

The experiments were generally carried out in the following way: The loop was primarily heated to the desired temperature and maintained in a steady state condition for 1 or 2 hours, in order to ensure a well defined basis line. The components under investigation were added by means of the filling tap. They are either in a concentrated solution in the basic fluid (usually OMD) or dissolved in a few milliliters of water. During the addition circulation of the fluid was stopped. After extensive rinsing of the filling tap the filling valve was closed and circulation reinitiated. After each test compound addition several hours of steady state operation followed.

3. TEMPERATURE EFFECT

The electrical conductivity of organic substances is severely influenced by temperature.

This effect has been investigated in the present equipment, either by continuous recording of the conductivity during gradual heating or cooling, or by maintaining the loop at definitive temperatures for a prolonged period.

The fluid under investigation was the tertiary eutectic mixture of biphenyl, o- and m-terphenyl, manufactured by Progil (France) under the name of OMD. The specifications of the product are:

Biphenyl	:	25-27 %w
Orthoterphenyl	:	53-55 %w
Metaterphenyl	:	17-19 %w
Paraterphenyl	:	<1 %w

Four experiments have been carried out, CC-I, CC-II, CF-I and CF-II. The impurity contents in these experiments were (ppm):

	CC-I	CC-II	CF-I	CF-II
Chlorine :	0.1	0.1	1.5	3.5
Ash :	1	2	<2	<2
H_2O :	13	16	15	17
Oxygen :	500	800	n.d.	n.d.

The results are shown in Fig. 3.

It appears that the slopes of all curves are approximately equal, but that large differences in electrical conductivity may occur, caused by impurities.

Run CC-I has been started with clean coolant. The temperature dependence has been determined and subsequently the loop has been maintained at 200°C for approximately 50 hours. During this period the ash and oxygen content of the fluid increased from 1 to 2 ppm (ash) and from 500 to 800 ppm (oxygen). Due to the increase of the impurity content the electrical conductivity increased from 1.3 to 4.4 picomho. cm^{-1} at 50°C and from 47 to 150 picomho.cm^{-1} at 150°C.

The fluid used in run CF-I was primarily used in run CE during which trichloroethylene (7.3 ppm Cl), sodium chloride (2 ppm Cl) and hydrochloric acid (3 ppm Cl) have been added. It appeared that these impurities are gradually adsorbed by the quartz wool filter (see Ch. 5), so that the chlorine content at the end of run CE (and at the start of run CF-I) was only 1.5 ppm. During CF-I the quartz wool filter was removed and the temperature effect determined by heating the loop with simultaneous recording of the electrical conductivity.

It is remarkable that the electrical conductivity measured in run CF-I is practically equal to the values measured in run CC-I, in spite of the higher chlorine content of the fluid used in CF-I. The residual chlorine is most probably bound to trichloroethylene or sodium chloride, which have no influence on the conductivity under the present conditions (see Ch. 4.2.).

Run CF-I was immediately followed by run CF-II, only an addition of 2 ppm chlorine in the form of $FeCl_3.6H_2O$ has taken place. This addition caused an increase of the conductivity from 2.1 to 40.5 picomho.cm^{-1} at 60°C and from 240 to 3000 picomho.cm^{-1} at 200°C. Above 200°C adsorption of the ferric chloride at the walls of the loop becomes noticeable and consequently deviation of the conductivity/temperature curve occurs.

By regression analysis the equations relating the electrical conductivity and the temperature have been determined. The equations are:

Run CC-I : $\log K = 7.010 - 2.254 \times (1000/T)$
Run CC-II : $\log K = 6.961 - 2.031 \times (1000/T)$
Run CF-I : $\log K = 7.327 - 2.340 \times (1000/T)$
Run CF-II : $\log K = 8.021 - 2.127 \times (1000/T)$

where K = electrical conductivity (picomho.cm^{-1})
T = absolute temperature (°K)

It follows that the slopes of the curves for more or less polluted fluids are approximately equal to the slope of the curve for clean coolant (CC-I).

For this reason it is concluded that for possible temperature corrections the slope of the conductivity/temperature relation for virginal OMD can be taken:

$$\frac{d(\log k)}{d(1000/T)} = 2.25.$$

4. EFFECT OF IMPURITIES

4.1. Ash content

In the preceding chapter it has already been mentioned that an increase in ash content in run CC-I and CC-II caused an important increase of the electrical conductivity.

An analogous effect has been found in run CB, which was carried out with Monsanto HB-40, which is a mixture of partly hydrogenated terphenyls (40-60 % of saturation).

This run was planned as a long duration run (about 100 h) for watching the eventual drift of the signal corresponding with the electrical conductivity.

A steady increase of the conductivity was observed, which was too pronounced to be explained by drift of recorder or amplifiers. Samples taken every 24 hours revealed a steady increase of ash content, probably due to wearing of the seals of the centrifugal pump.

The results of run CB are given in Table I and Fig. 4.

TABLE I

Results of run CB.

Sample	Time (h)	Loop temp. (°C)	El. cond. (picomho.cm^{-1})	El. cond. converted to 150°C (picomho.cm^{-1})	Ash content (ppm)
CB-0	0	64	0.45	9	1
CB-1	20	152	41	38	1
CB-2	42	200	11500	3260	3
CB-3	66	123	2380	5360	6
CB-4	90	153	6170	5670	10

It is noted that during the run the chlorine content remained essentially constant (approximately 0.2 ppm).

It appears that the conductivity steeply rises when the ash content increases from 1 to 6 ppm. Above 6 ppm the conductivity remains essentially constant.

The effect of ash content on conductivity is much more pronounced in run CB than in run CC (preceding chapter). In run CB an increase of the ash content from 1 to 3 ppm caused a rise of conductivity from 38 to 3260 picomho.cm^{-1} at 150°C, whereas in run CC an increase from 1 to 2 ppm caused a jump of the conductivity from 47 to 150 picomho.cm^{-1} at 150°C.

It must be noted that 1 to 2 ppm is very near to the detection limit for the ash analysis and that, moreover, the runs CB and CC have been carried out with two different fluids, HB-40 and OMD-Progil.

For these reasons it is preferred not to draw definite conclusions from the above mentioned conductivity values.

After replacing the graphite seals of the centrifugal pump by seals made from asbestos and modification of the quartz wool filter, no increase of the ash content by wear has been encountered any more.

4.2. Chlorine

The effect on the electrical conductivity of the chlorine content has been studied by the addition of known quantities of a number of well defined compounds. The results of the experiments are summarised in Table II.

It appears that five of the ten investigated compounds provoke a positive influence on the conductivity, i.e. ferric chloride, aluminium chloride, hydrogen chloride, zirconium tetrachloride and aniline hydrochloride.

The effect is clearly concentration dependent.

The other five compounds (sodium chloride, zirconium oxychloride, Arochlor*), polydichloroethylene and trichloroethylene) did not show an appreciable effect on the conductivity.

These results confirm the conclusions of Van Rutten et.al. [6] who found that organic bound chlorine has no effect on the conductivity. However, it appears that certain inorganic compounds (sodium chloride and zirconium oxychloride) have no effect either.

This is probably due to insufficient dissociation of these compounds in the organic medium with very low water content. In this context it is noted that the solubility of, for instance, sodium chloride in OMD is extremely low, whereas ferric and aluminium chloride are readily soluble in concentrations up to 100 ppm. This points to a higher affinity of the latter compounds to the organic medium, possibly leading to a better dissociation.

The results have been quantitatively evaluated by plotting the increase of the electrical conductivity caused by addition against the added quantity, expressed as chlorine concentration (Fig. 5).

It appears that the influence is independent of the type of cation present, but is a function of the chlorine concentration only. The specific effect is most pronounced for the first 2 ppm chlorine added; at higher concentrations the curve tends to flatten off.

It is important to note that the measured values for aniline hydrochloride coincide well with the other measurements. This means that also chlorine from organic components may contribute to the increase of the electrical conductivity, provided that the compound is sufficiently dissociated in the medium.

(*) Arochlor is a trade name for a chlorinated biphenyl, chlorine content approximately 50 %w.

TABLE II

Effect of chlorine addition on the electrical conductivity of OMD.

Added Compound	Quantity (ppm Cl)	Electrical conductivity (picomho.cm^{-1})			Temperature (°C)
		Before addition	After addition	Increment	
$FeCl_3.6H_2O$	0.1	63	97	34	150
"	0.2	54	132	78	150
"	0.4	88	282	194	150
"	0.5	32	246	214	150
"	1.0	40	440	400	150
"	1.0	238	783	545	150
"	2.0	60	1000	940	150
"	2.0	185	862	677	150
"	2.8	94	792	698	150
HCl	0.1	114	238	124	150
"	0.2	158	321	163	150
"	0.2	123	290	167	150
"	0.4	106	202	96	150
"	0.5	194	484	290	150
"	0.8	62	290	228	150
"	1.0	246	783	537	150
"	1.6	89	308	219	150
NaCl	2.0	230	230	-	200
"	5.0	625	616	-9	200
$AlCl_3.6H_2O$	0.2	156	264	108	150
"	0.5	203	466	263	150
"	2.0	347	906	559	150
$ZrCl_4$	0.2	1495	1670	175	150
"	1.0	968	1760	792	150
"	2.0	713	986	273	150
$ZrOCl_2.8H_2O$	0.2	1055	970	-85	150
"	1.0	1055	1055	-	150
Aniline-hydrochloride	0.5	1055	1410	355	150
"	1.0	3780	5020	1240	200
"	2.0	4140	6420	2280	200
"	5.0	2730	6340	3610	200
" *)	1.0	1075	1425	350	150
" *)	2.0	1175	1825	650	150
" *)	5.0	775	1800	1025	150
Arochlor	2.0	176	185	9	150
"	4.0	185	185	-	150
Polydichloroethene (Saran)	0.2	1500	1500	-	150
Trichloroethene	0.3	62	60	-2	150
	1.0	58	57	-1	150
	2.0	60	58	-2	150
	4.0	54	52	-2	150

(*) Calculated from the measured values at 200°C.

4.3. Various components

Besides the influence of chlorine, also the effect of some sulphur compounds has been investigated.

The results of these experiments are shown in Table III. This table also contains the results of some measurements with water. The possible effect of the water concentration has been checked since many additions were done in aqueous solution. It is found that water does not have any significant influence on the conductivity within a concentration range from 100 - 300 ppm.

The quantities of water added during the tests are always in this order of magnitude. The conclusion is that the addition of water in the form of aqueous solutions during the testing of the various compounds does not present a disturbing influence.

The results of the tests with sulphur confirm those effectuated with chlorine. Undissociated compounds (thiophene) have no influence. Also phenylmercaptane does not have any effect because its degree of dissociation is presumably insufficient. The well dissociated compound sulphuric acid has a distinct positive effect which is of the same order of magnitude as found for chlorinated compounds.

At higher concentrations (10 and 100 ppm) the effect is relatively smaller than the effect of the addition of 1 ppm which again indicates a non-linearity of the conductivity/concentration curve.

TABLE III

Effect of sulphur addition on the electrical conductivity of OMD.

Added compound	Quantity (ppm S)	Electrical conductivity (picomho.cm^{-1})			Temperature (°C)
		Before addition	After addition	Increment	
Sulphuric acid	1	2590	3050	460	150
	10	1580	2200	620	150
	100	825	1600	775	150
Phenyl mercaptane	1	775	765	-10	150
	3	755	740	-15	150
	100	1410	1410	-	150
Thiophene	0.2	246	246	-	112
	2	246	246	-	112
	100	1410	1410	-	150
Water	100	2820	2820	-	150
	200	2290	2380	90	150
	300	2380	2380	-	150

5. ADSORPTION IN THE QUARTZ WOOL FILTER

It has already been mentioned in Ch. 3 that chlorine is adsorbed by the quartz wool filter.

There are various arguments in favour of this statement:

1) Chlorine analyses of samples, taken during runs in which chlorine products have been added, gave much lower results than could be expected. For instance, the sample CD-15, taken after addition of 0.5, 1.0, 2.8 and 0.7 ppm Cl in the form of $FeCl_3.6H_2O$, plus 0.3 ppm Cl as HCl, contained only 1.5 ppm Cl, determinated by activation analysis.

   Another example is the one already mentioned in Ch. 3: After addition of trichloroethylene (7.3 ppm Cl), sodium chloride (2 ppm Cl) and hydrochloric acid (3 ppm Cl), the fluid contained only 1.5 ppm Cl at the end of run CE.

2) After each addition, causing an increase in conductivity, a gradual decrease of the conductivity is observed. An illustration of this effect is given in Fig. 6, showing the path of the electrical conductivity during 100 hours of run CD-I. The decrease of the conductivity is probably due to removal of the dissociated chlorine compound from the organic coolant.

3) After termination of run CD the quartz wool from the filter has been removed. The filter (volume 280 ml) contained 28 g of quartz wool from which two samples have been taken. One was heated to 100°C with 150 ml 30 % nitric acid, followed by a chlorine determination in the acid.

   This determination revealed a chlorine content of the quartz wool of 0.18 %. The other sample was washed with 150 ml HB-40 at 150°C. A chlorine determination in the washing fluid followed. By this method the chlorine content of the glass wool was found to be 0.29 %.

During run CD a total quantity of 340 mg chlorine has been added. At the end of the experiment there were approximately 4 ppm in solution, corresponding with 120 mg. Approximately 220 mg chlorine was thus adsorbed during the operation. If this quantity had been completely adsorbed by the quartz wool, this would correspond to a chlorine content of the quartz wool equal to 0.78 %.

It appears that 37 % of the total quantity of lost chlorine has been found in the quartz wool filter, with the aid of rather primitive analytical methods.

The three above mentioned points are considered sufficient for justification of the statement that adsorption of chlorine by the quartz wool filter takes place.

In this case it is interesting to investigate the rate of adsorption and possibly the saturation of the filter.

To this end the increase of the electrical conductivity has been used as a yardstick for the chlorine content of the organic coolant taking the curve of Fig. 5 as a standard. In this way the adsorption rate can be calculated from the gradual decrease of the conductivity after each addition. Division of the adsorption rate by the chlorine concentration yields the adsorption rate constant, since the former is proportional to the chlorine concentration. These data are given in Table IV, in which also the total quantity of chlorine adsorbed is reported.

A plot of the adsorption rate constant against the quantity of chlorine adsorbed is given in Fig. 7.

For elucidation of Fig. 7 it should be noted that during the runs CC, CD-I and CD-II the filter has not been changed. At the end of run CC the organic fluid has been replaced. Between run CD-I and CD-II the loop was not operated for a period of 15 days and cooled down to room temperature. It is remarkable that after this rest period a decrease of the electrical conductivity of the organic liquid from 175 to 62 picomho.cm^{-1} at 150°C and a certain reactivation of the quartz wool filter (see Fig. 7) were observed.

From Fig. 7 it appears that the quartz wool filter has to be charged with approximately 0.5 $mg.g^{-1}$ of chlorine to attain its maximum adsorption efficiency. From 0.5 to 5.5 $mg.g^{-1}$ the activity rapidly decreases.

After the plant had been down for 15 days, the activity again obtained practically its maximum value, but decreased very fast in the course of run CD-II for an incremental charge of about 1.5 $mg.g^{-1}$.

A thorough investigation of the adsorption of impurities on the quartz wool filter falls outside the scope of this report, but is can be concluded that a densely packed quartz wool filter (density 0.1 $g.cm^{-3}$) can operate as an effective dechlorinating agent in organic loops, if not charged with more than 5 $mg.g^{-1}$.

TABLE IV

Adsorption of chlorine on the quartz wool filter at 150°C

Chlorine content (ppm)	Adsorption rate (mg Cl per g of quartz wool per hour)	Adsorption rate constant (h^{-1})	Adsorbed chlorine (mg Cl per g of quartz wool)
	RUN CC		
1.72	1.77	1030	0.45
0.99	1.33	1340	1.23
0.52	0.62	1200	1.73
0.29	0.19	664	1.98
0.17	0.06	375	2.11
0.75	0.79	1060	2.31
0.47	0.43	910	2.61
0.30	0.15	500	2.80
0.20	0.05	270	2.90
	RUN CD-I		
0.34	0.23	695	3.07
0.20	0.08	395	3.22
0.11	0.02	225	3.32
0.88	0.20	220	3.63
0.60	0.11	180	3.93
0.44	0.06	145	4.10
0.35	0.03	95	4.20
0.29	0.03	125	4.26
2.07	0.15	75	4.58
1.81	0.12	70	4.86
1.55	0.08	50	5.14
1.27	0.05	35	5.44
1.04	0.05	45	5.69
0.87	0.04	45	5.87
	RUN CD-II		
0.45	0.32	715	6.50
0.34	0.08	255	6.62
0.28	0.04	155	6.68
0.25	0.02	85	6.72
0.51	0.43	840	6.82
0.41	0.19	470	6.93
0.35	0.04	120	7.00
1.08	0.19	180	7.06
0.94	0.21	230	7.21
0.78	0.12	150	7.38
2.24	0.34	155	7.61
2.03	0.16	80	7.83
1.88	0.16	85	7.99
3.87	0.28	70	8.24
3.63	0.22	60	8.49

TABLE IV

(continue)

Chlorine content (ppm)	Adsorption rate (mg Cl per g of quartz wool per hour)	Adsorption rate constant (h^{-1})	Adsorbed chlorine (mg Cl per g of quartz wool)
	RUN CE (New filter)		
0.16	0.06	405	0.02
0.13	0.03	495	0.05
0.11	0.03	290	0.07
0.41	0.06	155	0.12
0.35	0.06	180	0.18
0.46	0.17	370	0.32
0.30	0.17	570	0.49
0.16	0.13	805	0.64

6. CONCLUSIONS

The work described in this report leads to the following general conclusions:

1) The electrical conductivity of organic liquids increases substantially with increasing concentrations of dissociable compounds.

2) Small quantities of inorganic chlorine compounds (like $FeCl_3$, $AlCl_3$, HCl ...) which are probably dissociable in organic media, cause an important increase of the electrical conductivity. In this way concentrations down to 0.1 ppm can be detected. The obtained signal is proportional to the chlorine concentration.

3) Chlorine bound in the greater part of organic compounds has no influence on the electrical conductivity under the present test conditions. The absence of a response is most probably due to the fact that these compounds are undissociable.

4) Other impurities, causing an increase of the ash content of several ppm, may enhance the electrical conductivity to the same or to a larger extent than caused by small quantities of chlorine.

5) Chlorine containing compounds are readily adsorbed by the quartz wool filter until saturation which is reached at approximately 6 mg of chlorine per gram of quartz wool.

To these conclusions an important addition has to be made: In Canada extreme fouling and catastrophic hydriding of zirconium alloys has been observed when chlorine contamination occurred. In both instances, the manner in which the chlorine was chemically bound, was found to be most important. Inorganic compounds ($FeCl_3$, HCl) have the most significant effects on both fouling and hydriding. The more stable chlorine compounds (chlorobiphenyl and chloroterphenyls) were the less deleterious [2].

However, it is probable that by radiolysis and pyrolysis under reactor conditions, gradual decomposition of the inactive compounds to inorganic chlorine compounds (e.g. HCl) will occur. This would again increase the fouling and hydriding potential of the organic liquid.

It follows that chlorine compounds, active as fouling agents, cause an increase of the electrical conductivity. Compounds which do not influence the electrical conductivity are also apparently inactive as fouling promotors. If these inactive compounds are decomposed under formation of active chlorine, the latter will again provoke an increase of the electrical conductivity.

It appears that in this case the electrical conductivity is an excellent yardstick for the fouling potential.

From these remarks it is concluded that continuous recording of the electrical conductivity in organic loops of high purity is an utmost useful operation; any increase of the conductivity is caused by an increase of the impurity content.

Finally, it is noted that a complete elucidation of the phenomena of electrical conductivity and fouling potential in organic media falls outside the scope of the present study. To reach this aim much additional fundamental work will be necessary.

REFERENCES

[1] "The Orgel Program",
EUR 1830, Brussels (1964).

[2] Hatcher S.R., Finlay B.A., Smee J.L.,
A.E.C.L. 2642, May 1966.

[3] Imarisio G.,
"Zirconium Alloys in Terphenyls", paper presented at the ANS meeting 1964,
San Francisco, Ca, EUR 2549e (1965).

[4] Hatcher S.R., Tomlinson M.,
"Composition and Physical Properties of Organic Coolants", paper presented at the I.A.E.A. Panel, Vienna, May 1966.

[5] Stewart R.B., Smee J.L.,
"Methods for Analysis of Organic Coolants", paper presented at the I.A.E.A. Panel, Vienna, May 1966.

[6] Bauch R., Diletti F., Höpper M., Van Rutten F.,
"Quelques Effets Electriques dans le Terphényle",
EUR 3631f (1967).

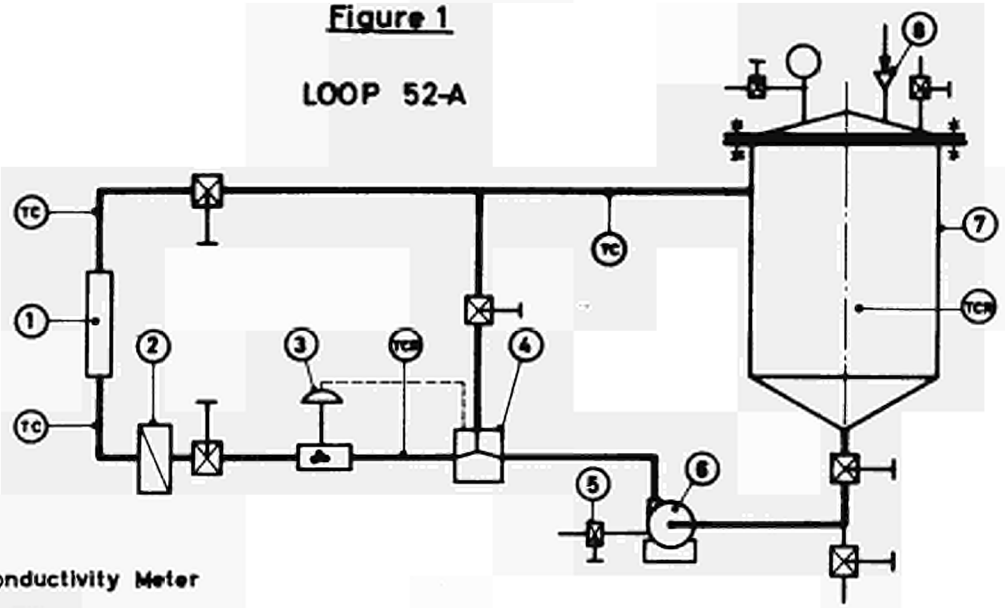
[7] Bret A., Stanchi L.,
"Conductancemètre pour Liquides Polarisables",
EUR 2633f (1966).

[8] Höpper M., Van Rutten F.,
"Conductivité Electrique des Terphényles",
Ispra Internal Report 632 (April 1964) (not availaible)

[9] Van Rutten F.,
Private Communication.

Figure 1

LOOP 52-A



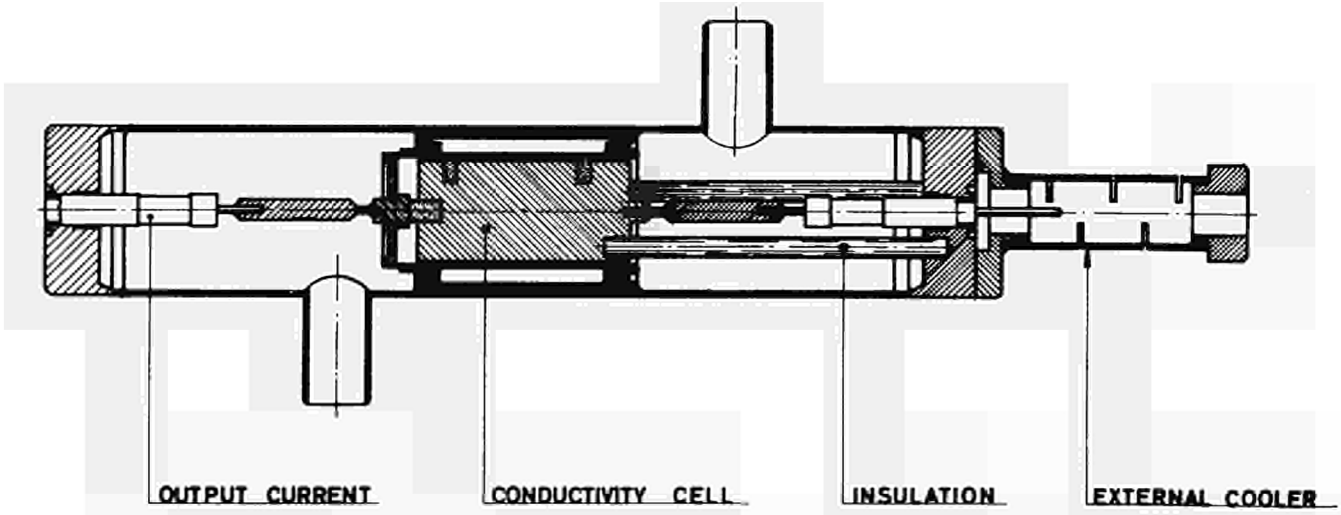
① Electrical Conductivity Meter
② Quartzwool Filter
③ Flowmeter
④ Motor Valve
⑤ FillingTap
⑥ Centrifugal Pump
⑦ Storage Tank
⑧ Bursting Disc

TCR Temperature Control and Regulation
TC Thermocouple

Loop Data		
Volume	: 30	l
Max Pressure	: 6,5	Kg/cm²
Max Temperature	: 400	°C
Flow	: 1000	l/h

Figure 2

CONDUCTANCE METER



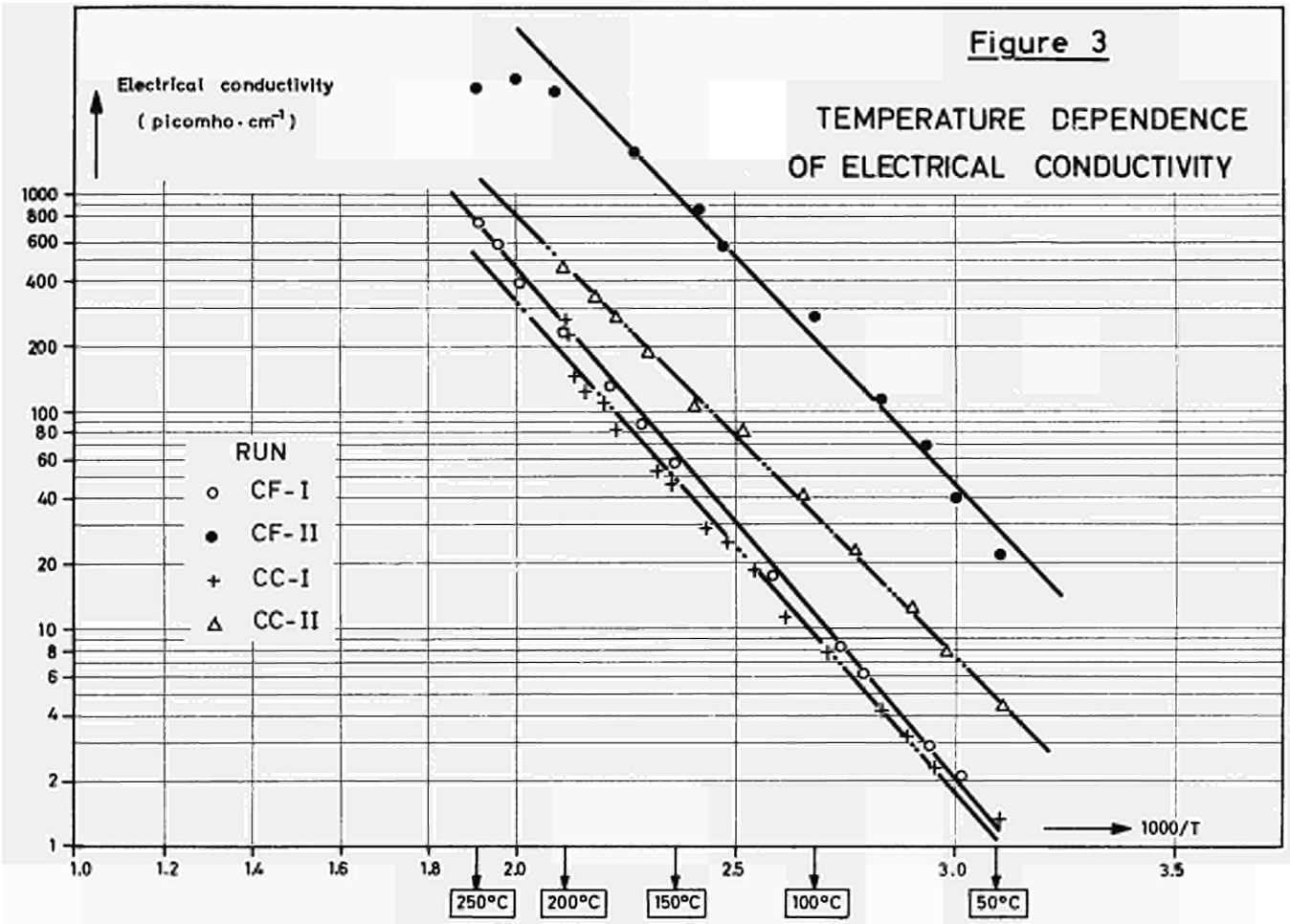


Figure 3
TEMPERATURE DEPENDENCE
OF ELECTRICAL CONDUCTIVITY
Electrical conductivity
(picomho · cm⁻¹)
RUN
CF-I
CF-II
CC-I
CC-II
1000/T
250°C
200°C
150°C
100°C
50°C

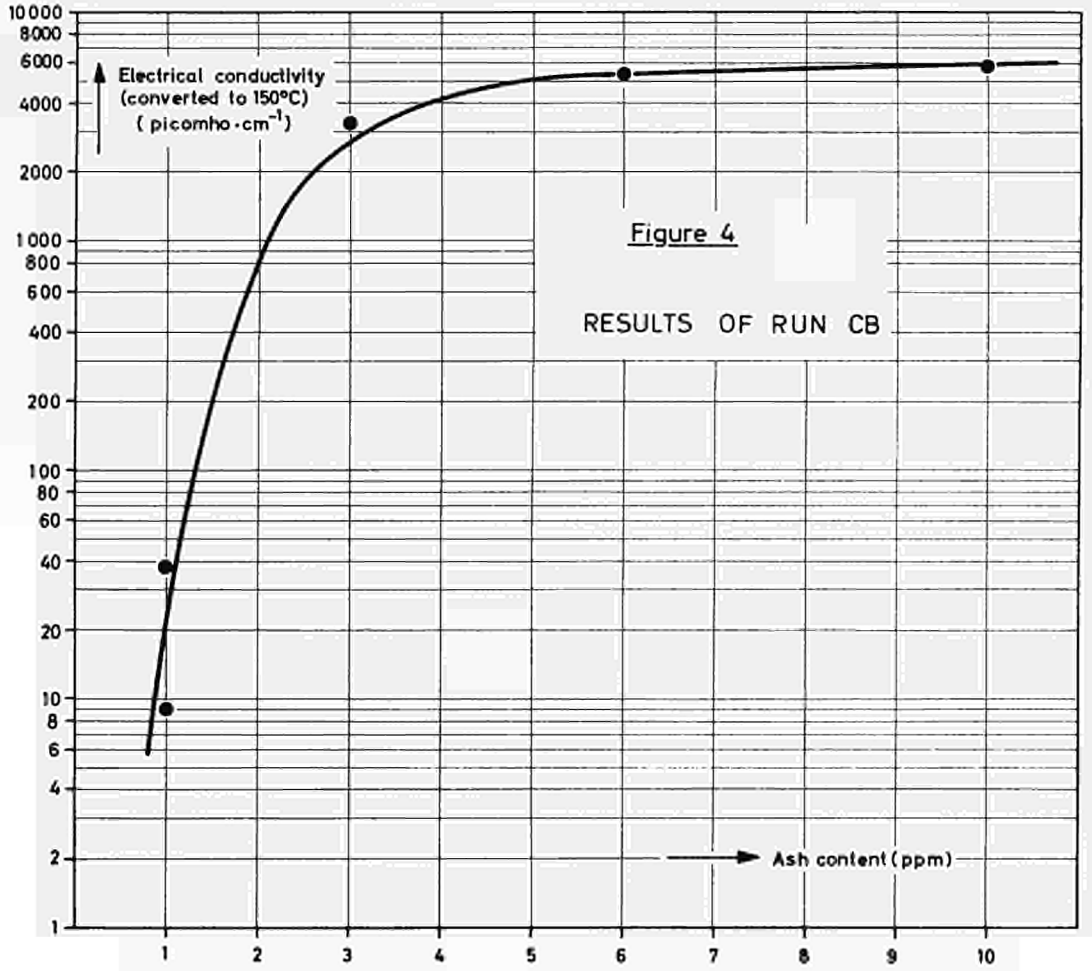


Figure 4
RESULTS OF RUN CB
Electrical conductivity
(converted to 150°C)
(picomho · cm⁻¹)
Ash content (ppm)

Figure 5

INFLUENCE OF CHLORINE ON ELECTRICAL CONDUCTIVITY AT 150°C

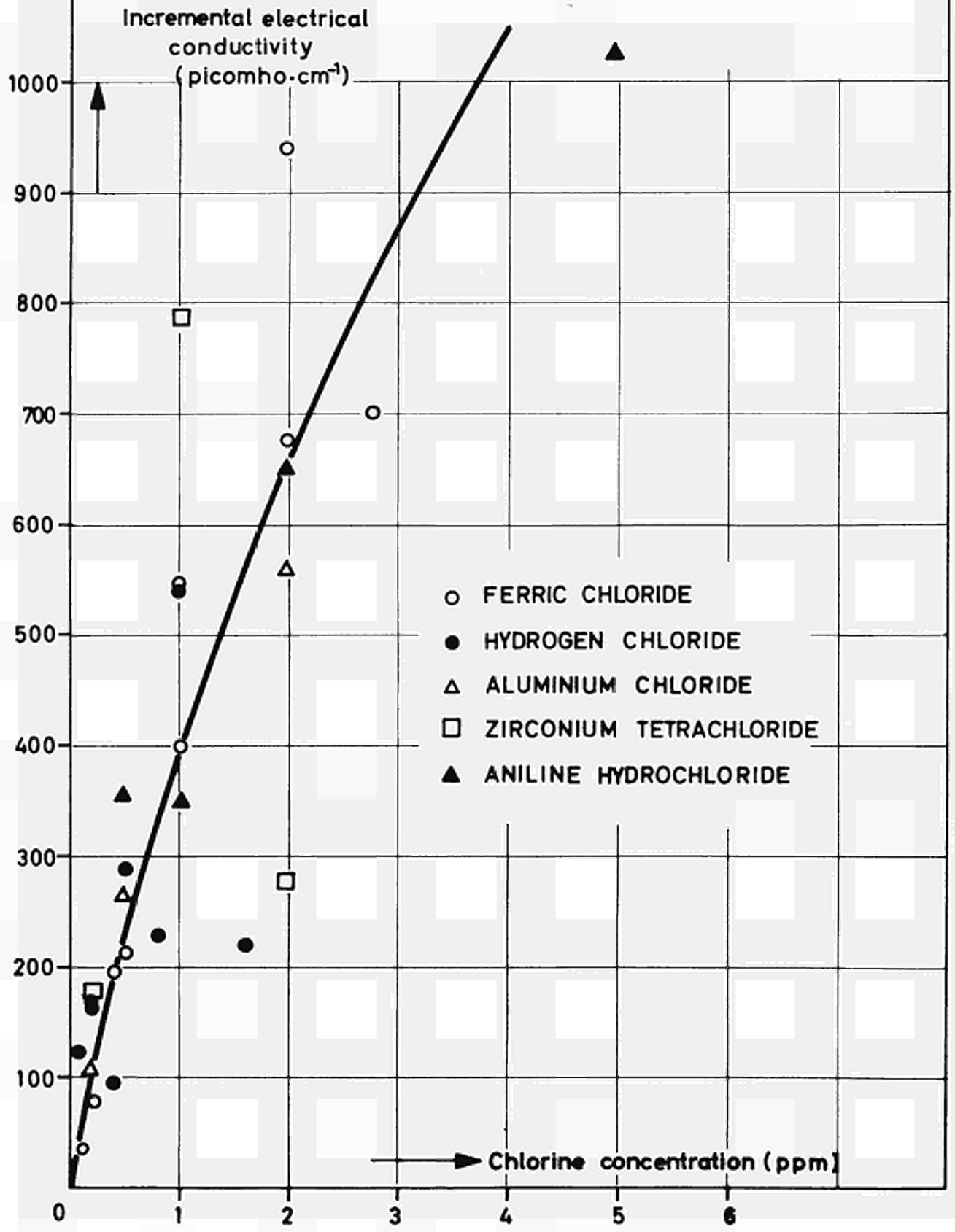


Figure 6

RESULTS OF RUN CD.
TEMP.: 150°C
FLOW RATE: 1000 Kg·h^{-1}
FLUID: OMD-PROGIL

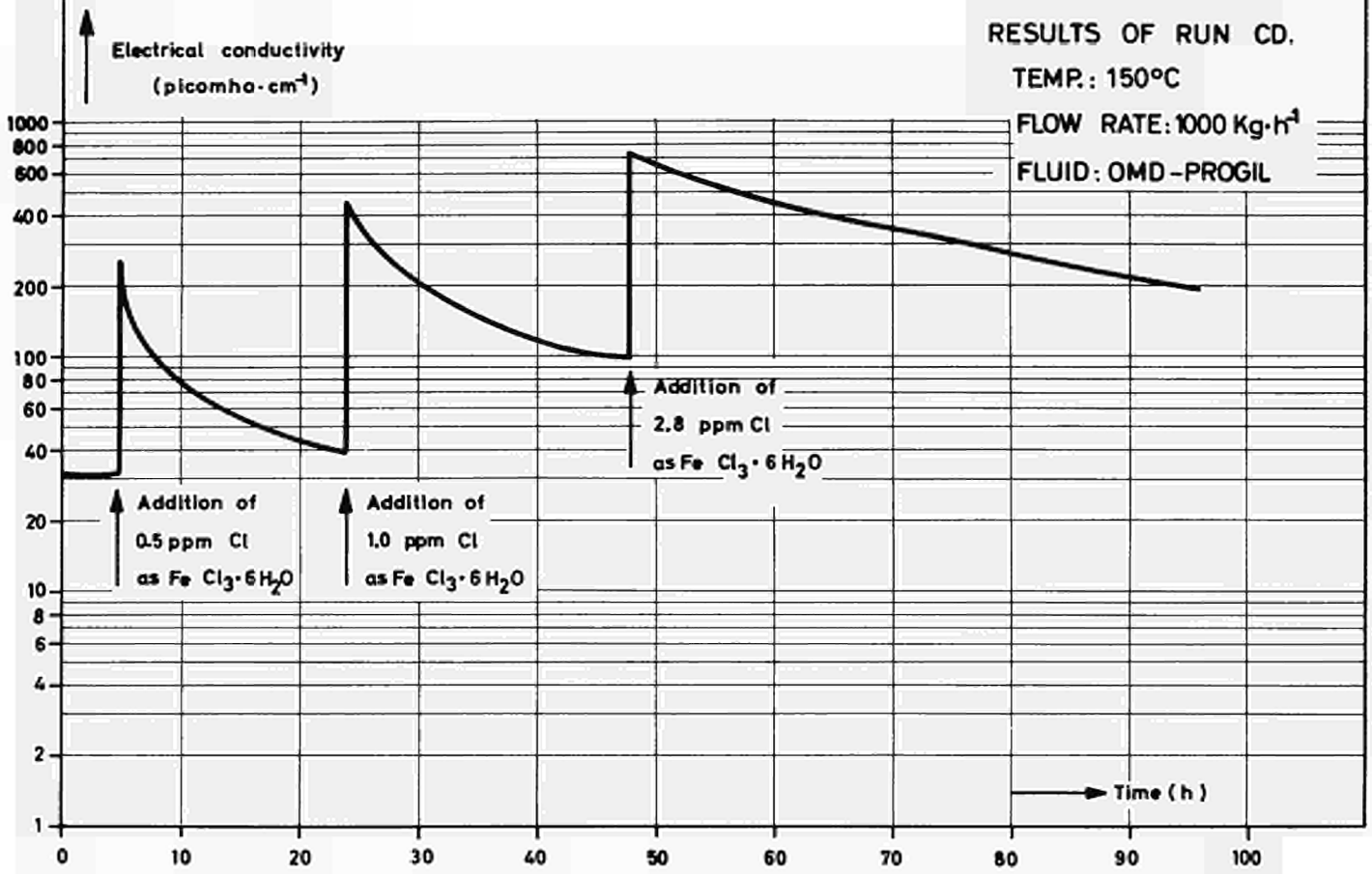
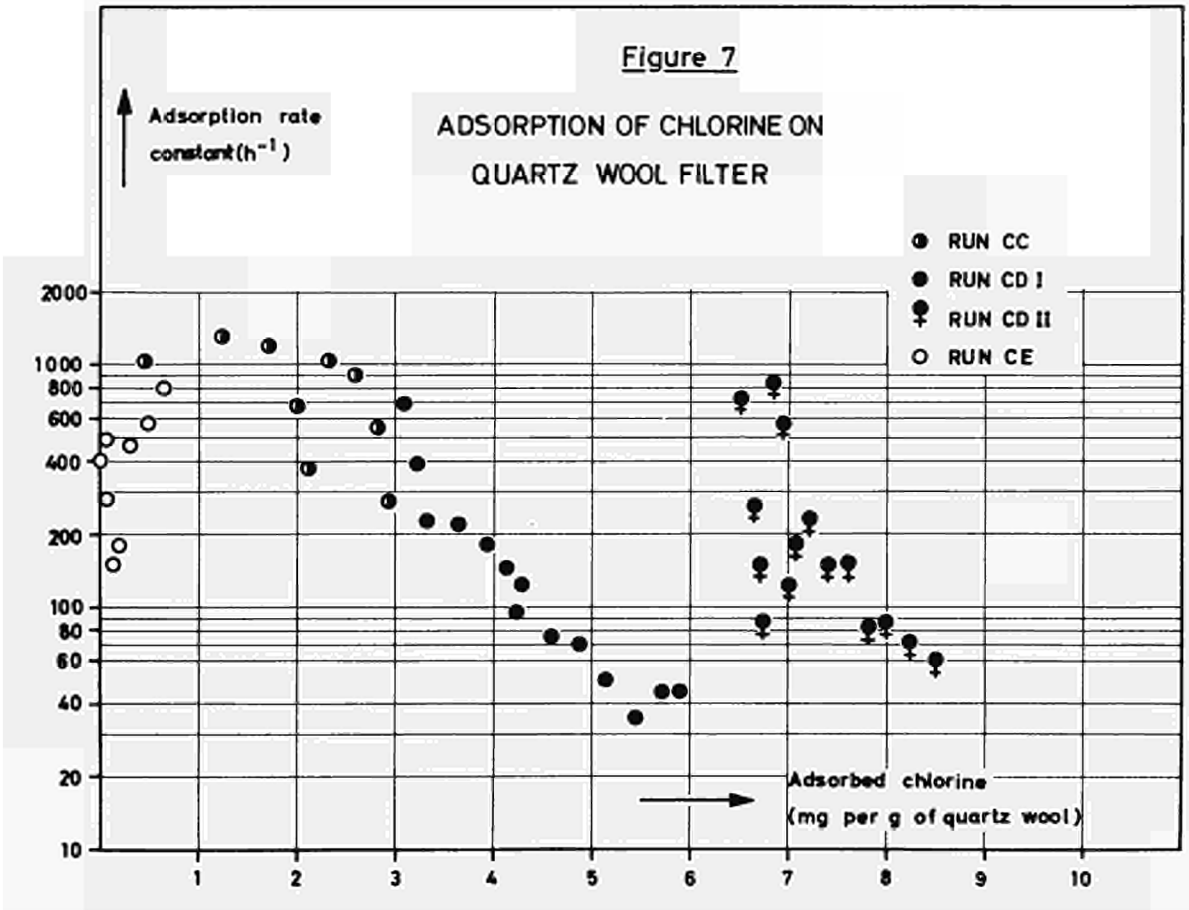


Figure 7

ADSORPTION OF CHLORINE ON
QUARTZ WOOL FILTER



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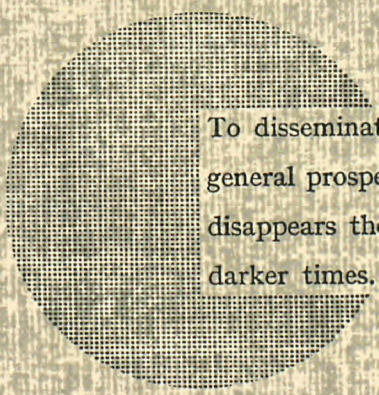

To disseminate knowledge is to disseminate prosperity — I mean general prosperity and not individual riches — and with prosperity disappears the greater part of the evil which is our heritage from darker times.

Alfred Nobel

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